The Impact of Emergency Department Crowding Measures on Time to Antibiotics for Patients With Community-Acquired Pneumonia

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Study objective: We seek to determine the impact of emergency department (ED) crowding on delays in antibiotic administration for patients with community-acquired pneumonia.

Methods: We performed a retrospective cohort study of adult patients admitted with community-acquired pneumonia from January 1, 2003, to April 31, 2005, at a single, urban academic ED. The main outcome was a delay (>4 hours from arrival) or nonreceipt of antibiotics in the ED. Eight ED crowding measures were assigned at triage. Multivariable regression and bootstrapping were used to test the adjusted impact of ED crowding measures of delayed (or no) antibiotics. Predicted probabilities were then calculated to assess the magnitude of the impact of ED crowding on the probability of delayed (or no) antibiotics.

Results: In 694 patients, 44% (95% confidence interval [CI] 40% to 48%) received antibiotics within 4 hours and 92% (95% CI 90% to 94%) received antibiotics in the ED. Increasing levels of ED crowding were associated with delayed (or no) antibiotics, including waiting room number (odds ratio [OR] 1.05 for each additional waiting room patient [95% CI 1.01 to 1.10]) and recent ED length of stay for admitted patients (OR 1.14 for each additional hour [95% CI 1.04 to 1.25]). When the waiting room and recent length of stay were both at the lowest quartiles (ie, not crowded), the predicted probability of delayed (or no) antibiotics within 4 hours was 31% (95% CI 21% to 42%); when both were at the highest quartiles, the predicted probability was 72% (95% CI 61% to 81%).

Conclusion: ED crowding is associated with delayed and nonreceipt of antibiotics in the ED for patients admitted with community-acquired pneumonia. [Ann Emerg Med. 2007;50:510-516.]

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INTRODUCTION

Background

Emergency department (ED) crowding is a public health crisis in the United States.[1-4] Factors that contribute to ED crowding include high patient volume, ED and hospital closures, high levels of hospital occupancy, and poor access to primary care.[5-14] ED patients are also increasingly older, more severely ill, and frequently experience long ED stays for diagnostic testing, treatment, and waiting for available hospital beds.[15,16] The nursing shortage compounds the problem and many EDs have trouble maintaining adequate staffing levels.[17] As a result, ED crowding is the functional state of high service demand coupled with a limited supply of space and personnel.

Importance

The association between ED crowding and poorer-quality emergency care has been difficult to establish. A recent study

Editor's Capsule Summary

What is already known on this topic

Process-of-care performance metrics often guide rewards and evaluations. Timing of antibiotics in community-acquired pneumonia is a current performance target.

What question this study addressed

Does emergency department (ED) crowding at 1 inner-city hospital alter the ability to deliver antibiotics within the target "within 4 hours of arrival" goal?

What this study adds to our knowledge

In this retrospective study of 694 patients with pneumonia treated in an ED performing beneath national medians overall and at less crowded times, crowding resulted in more frequent and longer delays in delivering antibiotics.

How this might change clinical practice

Time-based performance metrics in the ED can measure more than ED performance, and improvements can require interventions inside and outside the ED.

reported that 4 proposed measures of ED crowding are weak predictors of subjective ED quality.[18] The Joint Commission and the Centers for Medicare & Medicaid Services have proposed 2 time-sensitive indicators of ED quality: (1) antibiotic administration within 4 hours of arrival for admitted patients with community-acquired pneumonia (the measure is named PN-5b) and 2) percutaneous intervention within 2 hours for patients with acute myocardial infarction (the measure is named AMI-3a).[19] Although the use of these measures to define ED quality has been controversial, both measures are associated with improved patient care outcomes.[20-23] Our group recently studied the impact of measures of ED crowding on yearly performance data on AMI-3a and PN-5b in 24 academic centers.[24] We found that ED crowding measures predicted poorer performance on time-sensitive community-acquired pneumonia care (PN-5b) but not time-sensitive acute myocardial infarction care (AMI-3a). However, the analysis was at performed at the hospital level, and conclusions are limited by the ecologic nature of the study design, in that we could not demonstrate that individual patients with delayed treatment were actually treated during times of crowding.[25]

Goals of This Investigation

Our primary aim was to more directly test whether available measures of ED crowding, including measures of both input and output, were positively associated with delays in time to antibiotics for individual patients with community-acquired pneumonia managed in a large academic ED. We hypothesized that common measures of ED crowding would be predictive of a higher likelihood of failure to deliver antibiotics in the ED or within 4 hours.

MATERIALS AND METHODS

Study Design and Setting

We performed a retrospective cohort study of all adult patients 18 years and older who were admitted with an ED diagnosis of community-acquired pneumonia from January 1, 2003, to April 31, 2005. The study was performed in a large, urban, tertiary-care ED with an emergency medicine residency program. The ED has 25 individual patient rooms and 15 additional hallway treatment areas. During the study period, annual ED visits ranged from approximately 55,000 to 57,000 per year.

Data Collection and Processing

We identified all patients who were admitted from the ED with a principal diagnosis of community-acquired pneumonia (*International Classification of Diseases* codes 480.0 to 483.8, 485 to 486, and 487.0) through a computerized search of ED records. Medical records were reviewed by trained data abstractors to ensure that all patients indeed had been diagnosed with community-acquired pneumonia in the ED. The standard for classification as community-acquired pneumonia was documentation in the ED record of a diagnosis of pneumonia by the treating physician or objective radiographic evidence of "definite pneumonia," "possible infiltrate," "cannot rule out pneumonia" on either chest radiograph or computed tomography scan, as read by a board-certified radiologist. Abstracted data included demographic information and elements of the Pneumonia Severity Index, a validated 20-item index that predicts short-term mortality in patients with community-acquired pneumonia.[26] Elements of the Pneumonia Severity Index include demographic factors, nursing home status, coexisting illnesses, physical examination findings, and laboratory and radiographic findings. We also recorded the name of the first ED attending physician, with a note on the chart to reflect the provider who initially evaluated the patient. Where there was more than 1 admission per patient during the study period, only the first admission was used for analysis. More than 5% (n=40) of charts were randomly chosen and independently reviewed by a separate data abstractor to measure agreement.[27] Of the charts reviewed by both abstractors, there was 100% agreement for the data elements of the Pneumonia Severity Index and the ED attending physician assignment.

Measures of ED crowding were assigned to each patient according to the time of triage. We chose 8 measures of ED crowding to study because of their simplicity, ease of measure, and face validity. They were chosen and adapted from a list of potential measures that was published recently.[28] Data elements to measure ED crowding included input measures, throughput and output measures, and 1 global measure of ED crowding. The global measure of ED crowding was total patient-care hours (a sum of all the hours for all of the patients currently treated in the ED at triage). The 2 input measures were waiting room number at triage and the number of newly registered patients in the 6-hour period before triage. The 2 throughput measures were the arithmetic mean ED length of stay for

patients who were discharged from the ED in the 6-hours before triage and the arithmetic mean ED length of stay for admitted patients who were transferred to inpatient beds in the 6-hours before triage. Three output measures were the number of patients discharged from the ED in the 6-hour period before triage, the number of admitted patients who were transferred to inpatient beds in the 6-hours before triage, and the boarding burden (the total patient-care hours for those patients who had be admitted to the hospital as determined by a computerized bed request). All calculations were performed using Microsoft Access (Microsoft Corp, Redmond, WA) to query data in EMTRAC (University of Philadelphia, Philadelphia, PA), a computerized patient tracking and charting system. In EMTRAC, all elements of individual patient care timing, including patient triage time, room arrival time, physician order times (including medication, radiography, and bed request), and discharge time, are automatically time stamped.

The primary study outcome was whether time from patient triage until antibiotic administration was less than or equal to 4 hours. We chose this outcome because it is used as an objective measure of quality by the Centers for Medicare & Medicaid Services and The Joint Commission and because more proximal outcomes (such as time from triage to room arrival) capture only 1 step in the process of time to antibiotics.[29] Other automated data elements that were obtained included arrival mode (ambulance versus ambulatory) and nurse-assigned triage level. In our ED, we have a 4-level triage system (1, most urgent; 4, least urgent), which is assigned by the triage nurse to indicate to triage amount of time a patient may reasonably wait before being evaluated by a physician. Data were abstracted into a Microsoft Excel 2003 (Microsoft Corporation, Redmond, WA). All data were imported into Stata 9.0 (StataCorp, College Station, TX) for analysis. Our institutional review board found the study exempt from human subjects review.

Data Analysis

Data are reported with 95% confidence intervals, SDs, and interquartile ranges (IQRs). We used measures of ED crowding as continuous variables in the model but ultimately categorized the measures in quartiles for ease of presentation of effect sizes. Multivariable logistic regression modeling was used to determine adjusted effects of ED crowding measures as continuous variables on the primary outcome. For our modeling strategy, patient-level variables thought to be associated with the primary outcome (demographics, severity, triage class, and arrival mode) were picked a priori and kept in the multivariable model. Then, adjusted effects of combinations of input, throughput, and output variables were added to the model. Given the risk of multicollinearity among crowding variables, we dropped variables that were collinear and, within classes, picked the one with the best C statistics. To validate the model, we used bootstrapping with replacement. Reported CIs for the differences in the risk of outcome are based on robust estimates by clustering on the individual physician. Standard regression diagnostics were used and global goodness of fit was assessed using the Hosmer-Lemeshow test. We then calculated a predicted probability of the primary outcome for quartiles of individual crowding measures. We then calculated predicted probabilities at combinations of quartiles of crowding measures that were retained in the best multivariable model, adjusting for both patient and provider effects to determine an adjusted clinical effect of ED crowding on the primary outcome.

RESULTS

Over the study period, a total of 702 patients were identified according to principal discharge diagnosis of community-acquired pneumonia who were admitted to the hospital, and 694 patients met inclusion criteria. There were 32 ED attending physicians who admitted this group of community-acquired pneumonia patients. The median number of patients per physician was 16 (IQR 10 to 29). Forty-four percent (95% CI 40% to 48%) received antibiotics in 4 hours or less, and 92% (95% CI 90% to 94%) of all patients with community-acquired pneumonia received antibiotics in the ED. Median time from triage to antibiotics was 247 minutes (IQR 182-345). Table 1 compares characteristics of the 694 patients admitted with pneumonia by the primary study outcome.

Table 2 reports median ED crowding measures during the study period. After adjusting for patient demographics (age, sex, race), triage class, Pneumonia Severity Index, and mode of arrival (ambulance versus ambulatory), ED crowding measures retained in the best multivariable model were waiting room number (OR 1.05 for each additional patient [95% CI 1.01 to 1.09]), and mean length of stay for admitted patients (OR 1.14 for each additional hour [95% CI 1.04 to 1.25]). Table 3 shows the predicted probability of delayed (or no) antibiotics from the 2 models, using quartiles of waiting room number and recent (within 6 hours of arrival) mean length of stay for admitted patients, adjusting for both patient and provider effects.

LIMITATIONS

A primary limitation of this study is that it was performed at only 1 hospital, affecting the generalizability of this association. In addition, during the study period, the proportion of patients with pneumonia who received antibiotics in this ED was considerably lower than national benchmarks.[30] There exists the possibility that unmeasured confounding that we did not account for in this analysis explains this association. Also, because nurses manually enter time of administration after administering medications, there may have been discrepancies between the recorded time and the actual time of medication administration.

DISCUSSION

We demonstrate an association between ED crowding and the delivery of antibiotics within 4 hours of arrival to patients admitted with pneumonia in a large, academic ED. This relationship makes sense: when an ED is busier, delivery of a complex and time-sensitive intervention that involves multiple

Table 1. Patient characteristics of patients admitted with pneumonia (n=694).

Variables	Antibiotics in ≤4 h, %, (95% CI) [n=304]	No Antibiotics or Antibiotics >4 h, %, (95% CI) [n=390]
Age, y	57±18	57±18
Female	51 (45–56)	48 (43–54)
Race		
Black	55 (49–61)	54 (49–59)
White	39 (34–45)	37 (32–42)
Hispanic	5 (3–8)	7 (5–10)
Other	1 (0–3)	1 (0–3)
Arrived by ambulance	30 (25–35)	24 (19–28)
Triage level		
1	28 (23–34)	11 (8–15)
2	65 (60–71)	72 (67–76)
3	6 (3–9)	15 (12–19)
4	1 (0–2)	2 (1–4)
PSI class		
I	19 (15–24)	22 (18–27)
II	20 (16–25)	23 (19–28)
III	17 (13–22)	21 (17–25)
IV	36 (30–42)	28 (23–32)
V	8 (5–12)	6 (4–9)
PSI components		
Nursing home resident	7 (4–10)	6 (4–9)
Coexisting illnesses		
Neoplastic disease	22 (18–27)	21 (17–25)
Liver disease	2 (1–4)	3 (1–5)
Congestive heart failure	13 (10–17)	10 (7–13)
Cerebrovascular disease	10 (7–14)	5 (3–8)
Renal disease	12 (9–16)	9 (7–13)
Physical examination findings		
Altered mental status	4 (2–6)	2 (1–4)
Respiratory rate ≥30 breaths/min	11 (8–15)	5 (3–7)
Systolic blood pressure <90 mm Hg	5 (3–8)	3 (1–5)
Temperature <35°C (95°F) or 40°C (104°F)	43 (37–49)	36 (31–41)
Pulse 125 beats/min	19 (15–24)	12 (9–16)
Laboratory and radiographic findings		
Arterial blood pH <7.35	1 (0–3)	0 (0–1)
Blood urea nitrogen level 30 mg/dL	19 (15–24)	16 (13–20)
Sodium level <130 mmol/L	5 (3–8)	3 (2–6)
Glucose level 250 mg/dL	6 (4–9)	5 (3–7)
Hematocrit <30%	15 (12–20)	17 (14–22)
PaO_2 <60 mm Hg or O_2 sat <90%	10 (7–14)	4 (2–6)
Pleural effusion	14 (11–19)	15 (12–19)

Table 2. Median values of ED crowding measures in admitted patients with pneumonia (n=694).

ED crowding measures	Median Value (IQR)
Waiting room number at triage	6 Patients (3–10)
Number of newly registered patients in the 6 h before triage	44 Patients (32–54)
Number of discharged patients in the 6 h before triage	26 Patients (20–31)
Number of admitted patients transferred to inpatient beds in the 6 h before triage	5 Patients (3–9)
Mean length of stay for admitted patients in the 6 h before triage	8 Hours (7–10)
Mean length of stay for discharge patients in the 6 h before triage	4 Hours (3–5)
Boarding burden	13 Patient-hours (6–20)
Total patient care hours	108 Patient-hours (76–153)

steps such as the diagnosis of community-acquired pneumonia and delivery of antibiotics will be less efficient.[29] This confirms previous work in which we reported an association at the hospital level between ED crowding and performance on antibiotic timing (PN-5b).[24] To our knowledge, this is one of the first patient-level studies that reports a direct relationship between an exposure to ED crowding and poorer quality of care. Demonstrating this link between ED crowding and quality of care has been difficult to establish because of 4 fundamental issues: (1) there are few objective measures of ED quality, (2) there is no explicit definition for ED crowding, (3) few objective measures of ED crowding have predicted poorer-quality care or outcomes, and (4) there is no accepted standard of when an ED is too crowded. We will address each of these issues and their relation to our study design and results.

Table 3. Adjusted predicated probability of delayed (or no) antibiotics by quartiles of waiting room number, new ED patients and mean length of stay for admitted patients (n=694).*

		LOS for admitted patients			
		Lowest Quartile	**2nd Quartile**	**3rd Quartile**	**Highest Quartile**
Waiting Room Number	**Lowest Quartile**	0.31 (0.21–0.42)	0.44 (0.34–0.54)	0.50 (0.40–0.59)	0.59 (0.47–0.70)
	2nd Quartile	0.37 (0.26–0.49)	0.62 (0.49–0.72)	0.57 (0.47–0.67)	0.65 (0.52–0.76)
	3rd Quartile	0.45 (0.32–0.59)	0.56 (0.44–0.69)	0.62 (0.51–0.73)	0.75 (0.66–0.83)
	Highest Quartile	0.53 (0.40–0.66)	0.61 (0.49–0.71)	0.65 (0.55–0.74)	0.72 (0.61–0.81)

LOS, Length of stay.
†In the 6 hours before triage of a patient with pneumonia.
*Predicted probabilities are adjusted for the Pneumonia Severity Index Class (1, 2, 3 and compared to 4, 5), triage class, arrival mode, and patient demographics (age, sex, and race), and CIs account for clustering on individual attending physicians.

To address the first issue, even though the measurement of time to antibiotics in community-acquired pneumonia is controversial,[20] we thought that it was still appropriate in this retrospective study to use as a measure of ED quality. During the study period, early antibiotics in community-acquired pneumonia were gaining favor as an important element of ED care. More important, it is one of the only available time-sensitive standards for ED quality. As new objective standards for ED quality emerge, these standards should certainly be tested against measures of ED crowding. The second issue relates to the lack of an explicit definition for ED crowding. We propose that ED crowding be defined through its functional relationship with quality of care, as we did in this study. That is, a patient-level exposure to the objective administrative state of an ED at the time the patient arrives (waiting room number and average length of stay for admitted patients) to the ED is associated with an expected quality of care that the patient will receive. In this study, when exposed to a full waiting room and a full hospital (as indicated by a long average of length of stay for admitted patients), ED patients presenting with pneumonia will have only a 28% chance of receiving early antibiotics compared to a 69% chance when the number of patients in the waiting room is low and the length of stay for admitted patients is low. As a formal definition, we define a crowded ED as the administrative state of the ED in which expected quality of care for new and existing patients is diminished. Our data suggest that crowding can change the probability of substandard care (delayed administration of antibiotics) by 41 percentage points, a substantial effect. This relationship addresses the primary complaint about crowding: that emergency providers are unable to provide the highest quality service when the ED is crowded.[31] This definition is also practical from a research perspective because we can associate objective measures of crowding with objective measures of quality, as we did in this study.

We can then address the third issue: which indicators of ED crowding best predict quality of care? Understanding which measures are most predictive will be important in developing an index for crowding. Our results indicate that key measures of crowding include waiting room number, number of newly registered ED patients, and mean length of stay for admitted patients because of their strong relation to antibiotic timing in community-acquired pneumonia. Mean length of stay for discharged patients, total patient-care hours, and boarding burden were also predictive of antibiotic delays but had a wider variance. Interestingly, the most predictive variables for overall ED performance on time to antibiotics do not appear to be under the control of the individual ED provider. This supports what is a common and classic attribution error where ED providers are often blamed for poor ED performance. Our study suggests that ED performance depends not on the effort of individual ED clinicians but rather on institutional capacity outside of an individual's control. To enhance ED performance, hospital operations managers should consider focusing on improving modifiable system factors such as ED boarding and throughput times for bottleneck tasks such as radiology and laboratory testing. These operational strategies may be more effective than requiring ED providers to improve their individual performance on system factors not directly under their control.

The fourth question is, when is an ED too crowded? A surprising finding in this study is the lack of a specific threshold effect. Even in the second quartile of many measures, patients experienced a lower probability of receiving antibiotics early. If our goal in emergency care is to provide the highest quality care for every patient, this may mean that resources devoted to this ED have an insufficient buffering capacity and become saturated at low levels. Another possibility is that at low levels of crowding, the ED is overstaffed and patient demand should be more carefully matched with resource supply. Practically, when researchers aim to derive a specific cutoff for what defines a crowded state, they may want to consider basing this threshold on a clinically significant probability of poorer care quality or poorer outcomes for illnesses affected by crowding, such as the care of pneumonia.

When models to explain this association are constructed, the multivariable models that best predicted antibiotic timing were ones that included only 1 input measure (waiting room number) and 1 output measure (the average length of stay for admitted patients). An input-throughput-output model has been suggested as a conceptual model of ED crowding.[32] These data, however, expand on that model and suggest a simpler conceptual model for the impact of ED crowding on quality: an ED input and an ED output point. We detected independent

effects of ED crowding measures at each input/output point on ED quality, with the most predictive being patients awaiting inpatient beds (ie, boarding), the next most predictive being a measure of input (waiting room number or newly registered patients), and the least predictive being length of stay for discharged patients. We reported predicted probabilities of early antibiotic delivery according to these findings to estimate a clinical effect size. However, at the lowest levels of ED crowding, more than 1 in 3 patients did not receive early antibiotics. This is concerning and may indicate that patients experience long waits for care even when it is not crowded. However, it is also possible that this reflects difficulties in rapidly diagnosing patients with community-acquired pneumonia because some patients may not present with typical symptoms.[33,34]

The overall proportion of patients with pneumonia who received antibiotics within 4 hours in this study is considerably lower than national performance benchmarks.[30] Although the absolute impact of crowding on the process of care in this population was large, it is possible that in EDs with chronically high levels of ED crowding, this absolute effect of ED crowding on time to antibiotic receipt for patients with pneumonia is magnified. Because these EDs that are chronically crowded may also have poor overall flow and poorer turnaround times at multiple steps in the diagnosis of pneumonia, these delays may be exacerbated during episodes of high demand for time-sensitive care.[29]

In conclusion, we report a substantial impact of ED crowding on time to antibiotics in our ED. The most predictive models for this relationship involved waiting room number and average length of stay for admitted patients. These predictors were independent of patient level, and provider-level effects may be useful in an index of ED crowding.

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REFERENCES

1. Derlet RW, Richards JR. Overcrowding in the nation's emergency departments: complex causes and disturbing effects. *Ann Emerg Med*. 2000;35:63-68.
2. Lynn SG, Kellerman AL. Critical decision making: managing the emergency department in an overcrowded hospital. *Ann Emerg Med*. 1991;20:287-292.
3. Derlet R, Richards J, Kravitz R. Frequent overcrowding in U.S. emergency departments. *Acad Emerg Med*. 2001;8:151-155.
4. Institute of Medicine. Hospital-based emergency care: at the breaking point. 2006. Available at: http://www.nap.edu/catalog/11621.html#toc. Accessed January 24, 2007.
5. McCaig LF, Nawar EW. National hospital ambulatory medical care survey: 2004 emergency department summary. *Adv Data*. 2006;372:1-29.
6. McConnell KJ, Richards CF, Daya M, et al. Effect of increased ICU capacity on emergency department length of stay and ambulance diversion. *Ann Emerg Med*. 2005;45:471-478.
7. Derlet RW. Overcrowding in emergency departments: increased demand and decreased capacity. *Ann Emerg Med*. 2002;39:430-432.
8. Fatovich DM, Nagree Y, Sprivulis P. Access block causes emergency department overcrowding and ambulance diversion in Perth, Western Australia. *Emerg Med J*. 2005;22:351-354.
9. Rathlev NK, Chessare J, Olshaker J, et al. Time series analysis of variables associated with daily mean emergency department length of stay. *Ann Emerg Med*. 2007;49:265-271.
10. Forster A, Stiell I, Wells G, et al. Effect of hospital occupancy on emergency department length of stay and patient disposition. *Ann Emerg Med*. 2003;10:127-133.
11. Twanmoh JR, Cunningham GP. When overcrowding paralyzes an emergency department. *Manag Care*. 2006;15:54-59.
12. Asplin BR, Rhodes KV, Levy H, et al. Insurance status and access to urgent ambulatory care follow-up appointments. *JAMA*. 2005;294:1248-1254.
13. Begley CE, Vojvodic RW, Seo M, et al. Emergency room use and access to primary care: evidence from Houston, Texas. *J Health Care Poor Underserved*. 2006;17:610-624.
14. Lowe RA. How primary care practice affects Medicaid patients' use of emergency services. *LDI Issue Brief*. 2005;10:1-4.
15. Ackermann RJ, Kemle KA, Vogel RL, et al. Emergency department use by nursing home residents. *Ann Emerg Med*. 1998;31:749-757.
16. Schumacher JG. Emergency medicine and older adults: continuing challenges and opportunities. *Am J Emerg Med*. 2005;23:556-560.
17. Richardson SK, Ardagh M, Gee P. Emergency department overcrowding: the Emergency Department Cardiac Analogy Model (EDCAM). *Accid Emerg Nurs*. 2005;13:18-23.

18. Jones SS, Allen TL, Flottemesch TJ, et al. An independent evaluation of four quantitative emergency department crowding scales. *Acad Emerg Med*. 2006;13:1204-1211.
19. Joint Commission. *The Joint Commission for the Accreditation of Hospitals and Organization Specification Manual*. Available at: http://www.jointcommission.org/PerformanceMeasurement/PerformanceMeasurement/Current+NHQM+Manual.htm. Accessed February 20, 2007.
20. Pines JM. Profiles in patient safety: antibiotic timing and pay-for-performance. *Acad Emerg Med*. 2006;13:787-790.
21. Houck PM, Bratzler DW, Nsa W, et al. Timing of antibiotic administration and outcomes for Medicare patients hospitalized with community-acquired pneumonia. *Arch Intern Med*. 2004;164:637-644.
22. Meehan TP, Fine MJ, Krumholz HM, et al. Quality of care, process, and outcomes in elderly patients with pneumonia. *JAMA*. 1997;278:2080-2084.
23. Brodie BR, Stuckey TD, Wall TC, et al. Importance of time to reperfusion on 30-day and late survival and recovery of left ventricular function after primary angioplasty with myocardial infarction. *J Am Coll Cardiol*. 1998;32:1312-1319.
24. Pines JM, Hollander JE, Localio AR, et al. The association between emergency department crowding and hospital performance on antibiotic timing for pneumonia and percutaneous intervention for myocardial infarction. *Acad Emerg Med*. 2006;13:873-878.
25. Piantadosi S, Byar DP, Green SB. The ecological fallacy. *Am J Epidemiol*. 1988;127:893-904.
26. Fine MJ, Auble TE, Yealy DM, et al. A prediction rule to identify low-risk patients with community-acquired pneumonia. *N Engl J Med*. 1997;336:243-250.
27. Gilbert EH, Lowenstein SR, Koziol-McLain J. Chart reviews in emergency medicine research: where are the methods? *Ann Emerg Med*. 1996;27:305-308.
28. Solberg LI, Asplin BR, Weinick RM, et al. Emergency department crowding: consensus development of potential measures. *Ann Emerg Med*. 2003;42:824-834.
29. Pines JM, Morton MJ, Datner EM, et al. Systematic delays in antibiotic administration in the emergency department for adult patients admitted with pneumonia. *Acad Emerg Med*. 2006;13:939-945.
30. Williams SC, Schmaltz SP, Morton DJ, et al. Quality of care in U.S. hospitals as reflected by standardized measures, 2002-2004. *N Engl J Med*. 2005;353:255-264.
31. Magid DJ, Asplin BR, Wears RL. The quality gap: searching for the consequences of emergency department crowding. *Ann Emerg Med*. 2004;44:586-588.
32. Asplin BR, Magid DJ, Rhodes KV, et al. A conceptual model of emergency department crowding. *Ann Emerg Med*. 2003;42:173-180.
33. Metlay JP, Schulz R, Li YH, et al. Influence of age on symptoms at presentation in patients with community-acquired pneumonia. *Arch Intern Med*. 1997;157:1453-1459.
34. Waterer GW, Kessler LA, Wunderink RG. Delayed administration of antibiotics and atypical presentation in community-acquired pneumonia. *Chest*. 2006;130:11-15.

IMAGES IN EMERGENCY MEDICINE

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DIAGNOSIS:

Superior vena cava syndrome. The diagnosis was suspected according to the patient's physical examination but was proven with venography. A venous duplex test failed to reveal any thrombosis. A CT angiogram of the chest did not show a mass that could cause superior vena cava compression, nor did it demonstrate thrombosis. A transesophageal echocardiogram was obtained to rule out tamponade.

Superior vena cava syndrome is usually associated with external compression from intrathoracic masses, most commonly lung cancers.[1] Venous thrombosis associated with central venous catheters is increasingly being recognized as a cause of superior vena cava syndrome.[2,3] Our patient had a central venous catheter, and dehydration from gastroenteritis likely contributed to her acute presentation. Venography demonstrated superior vena cava stenosis and thrombosis (Figure 3). Thrombolytic therapy and angioplasty were required to relieve the obstruction (Figure 4). Within 4 days of treatment, her physical examination returned to normal (Figure 5).

REFERENCES

1. Rice TW, Rodriguez RM, Light RW. The superior vena cava syndrome: clinical characteristics and evolving etiology. *Medicine (Baltimore)*. 2006;85:37-42.
2. Greenberg S, Kosinski R, Daniels J. Treatment of superior vena cava thrombosis with recombinant tissue type plasminogen activator. *Chest*. 1991;99:1298-1301.
3. Rantis PC Jr, Littooy FN. Successful treatment of prolonged superior vena cava syndrome with thrombolytic therapy: a case report. *J Vasc Surg*. 1994;20:108-113.